PDES:
The Enterprise Data Standard

Preface

This Blue Book introduces concepts and fundamentals of the area of technology known as the Product Data Exchange Specification, or PDES. It was produced by the CASA/SME Technical Forum of the Computer and Automated Systems Association of the Society of Manufacturing Engineers. It is the first in a series of planned products relating to PDES. The objective is to answer basic questions about PDES, describe what this technology is all about, what directions it is heading and the kind of results it can achieve.

The Computer and Automated Systems Association of SME is a technical association functioning as an integral part of SME designed to advance and disseminate knowledge to those interested in the fields of computer and automated systems, CIM implementation and management as they relate to all aspects of the manufacturing enterprise.

CASA/SME and the Society of Manufacturing Engineers sponsored, in 1988 and 1989, clinics on the PDES standard and activities within PDES. This Blue Book is a membership benefit of the Computer and Automated Systems Association of SME.

Introduction

Computer systems are tools used to manipulate information in operating today's industries. Computers process management information for planning and control functions. They automate functions found in the operating divisions for design, manufacture and product support. On the shop floor, computers control process operations, resulting in faster machines and higher productivity. People use computers with spread sheets, databases and word processing systems throughout the business to improve their personal productivity, too.

With the power of computing applied, information gains value and becomes a strategic asset in the race for competitive advantage. Hardcoded reports become databases for adhoc query. Information is available faster and consequently, business management becomes proactive. Managers become closer to their products and markets by having information that is accurate as well as timely.

Companies are under pressure to reduce leadtime to market, reduce cost and improve quality. To gain more of a competitive advantage, companies share information about their products and processes between departments and even with trading partners. History demonstrates our desire to link, combine, connect and integrate manual and computer-based systems in our businesses. In today's terminology, we *integrate* everything. Computer-Aided Manufacturing, Computer Integrated Manufacturing, Computer Integrated Enterprise, etc. are all terms having integrate as the key word. Integration can mean the systems run on the same machine, use the same file format, share the same database, have a similar look and feel, and operate seamlessly.

Because organizations install different brands of computers, systems, databases, and communications—each with different functionality—the capability to exchange and share information is easily hampered. Data formats differ, as do file and data structures, and data content. To continue down the path of integration, companies push to develop tools and methods to solve these significant issues.

Efforts to improve the data exchange and sharing process between functions found in a manufacturing enterprise are gaining momentum in today's international marketplace. The Initial Graphic Exchange Specification (IGES) is an engineering data exchange specification supported by major CAD/CAM system vendors. IGES, developed initially in 1979, had a slow start in the early 1980s although it is being used successfully in production today. The Electronics Industries Association sponsor the Electronic Design Interchange Format (EDIF) for the transfer of electronic product design data like schematic, mask layout, logic models, netlist, and documentation data. In Europe, VDA is a mechanical design exchange format used primarily within the German automotive market. SET is sponsored by the French aerospace industry and is used to transfer data similar to that transferred by IGES. Although this is not an exhaustive description of data exchange standards, it does show the broad support of data exchange technology and the wide range of application with manufacturing industries.

The Product Data Exchange Specification (PDES) is a data description and format standard under development for the exchange and sharing of all data needed to fully describe a product and its manufacturing processes. PDES describes the information forming the "Information Resource Management and Communications — Common Data" ring surrounding the core of the CASE/SME Enterprise CIM Wheel as shown in Figure 1. The applications shown

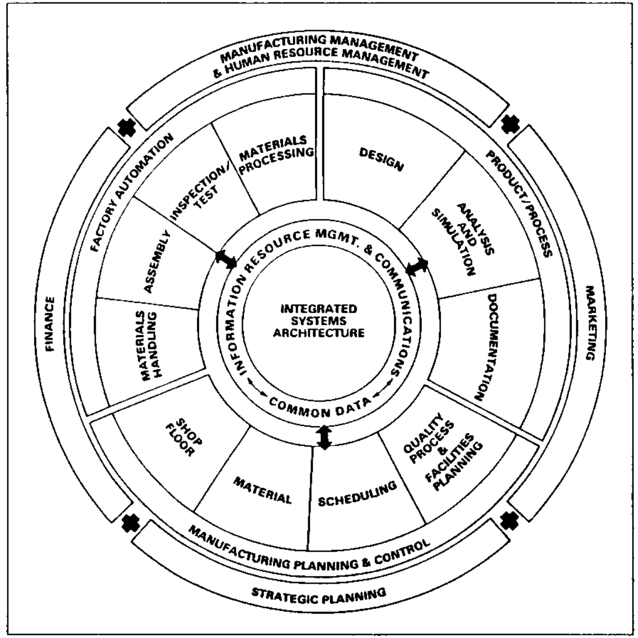

Figure 1. The CASA/SME CIM Enterprise Wheel.

around the CIM Wheel illustrate the broad scope of PDES, a specification designed to support the entire product lifecycle. This Blue Book provides a general introduction to the technology, development plans, organizations and benefits of PDES.

What Is PDES?

PDES can be viewed from several different viewpoints and is actually a compilation of many different activities. PDES is a standards development process. PDES is a combination of different technologies. PDES is an activity contributed by several different people from many companies and organizations.

A Standards Development Process. As a standards development process, PDES is an activity whose goal is to create an international standard for the exchange of product model data. The resulting standard is also a process whereby knowledge is created, knowledge is shared and documented as well. The standards development process is unusual because the standards activity is happening concurrently with the development of the technology. In most standardization processes, the technology is developed, stabilized and then becomes standardized. The PDES program is doing these concurrently.

Technology Development Process. The technology that's going into the development of the PDES program, can also be categorized in several different groups and technologies.

The first technology to be discussed is information modeling. Here, the purpose is to define and document the product data to be shared or exchanged between organizations and functions. Information modeling has become the modeling of knowledge:

- knowledge about the enterprise,
- knowledge about the products that the enterprise produces,
- knowledge about the process whereby those products are also produced.

Along with information modeling is the technology of information management. Once the information has been modeled, there must be a way of storing and retrieving it. Information management technology is also an important part of the technologies providing the foundation for the development of PDES. Information management is being stressed because of the different information used in the PDES program. Information management technology has to provide access to the PDES information, storage and retrieval of the PDES data, the ability to create new PDES data and modify it.

The third area of major group or category of technology is downstream technology that uses PDES data. People often confuse the fact that PDES is frequently tied to downstream technology for the purpose of demonstrating PDES capabilities. For example, a computer-aided process planning system, an example of downstream technology, is often an information starved application that needs to have a PDES database in order to become fully automated. From the history of the development of PDES, we find that downstream applications provide excellent sources for the requirements of a PDES database or a PDES system. Those downstream applications like computer-aided process planning, group technology, classification and coding, machine parts programming, robotics programming, inspection system programming, all require PDES data as input and can also store back data into the PDES database.

These are all groups of technologies which together become part of the PDES program upon which the PDES program relies and through which the PDES program will be demonstrated to those in the manufacturing and engineering communities.

An Activity. PDES is also an activity. The PDES program started in 1984 as an spin off of the IGES activity. It has been administered by the National Institute for Standards and Technology (NIST). NIST administers the PDES program through its IGES/PDES organization. The people involved with PDES are from companies throughout the world. They volunteer their time and company resources to work on the development of the PDES specification and on the standardization of PDES.

The activity of PDES can also be traced back to technology development projects funded by the Air Force Manufacturing Technology Program. Research and development programs have been funded by the Air Force since the early 1980s working on the technologies underlying PDES and other activities related to PDES.

When asked, "what is PDES?" we get several answers: PDES is a standards development process; a goal of the PDES program is to create an international standard for the exchange and sharing of product model data; PDES is also a technology; PDES is a technology of information management, modeling, user technologies and implementation technologies related to the overall industry of CAD/CAM and CIM. And, PDES is an activity contributed to by companies in the United States government agencies, the Air Force, and other military branches of the Department of Defense. In the international community, a coordinated effort with similar objectives is called STEP — Standard for the Exchange of Product Model Data. PDES and STEP efforts combined are developing a single worldwide standard under the auspices of the International Standards Organization.

All of these viewpoints on PDES we hope to explain as you read this CASA/SME Blue Book. These different viewpoints enable us to create this description of the PDES program so that your company may become involved in the standards development process, understand the underlying technologies related to the PDES program, and become involved in PDES, the activity.

The requirements for PDES and all its related activities are:

- Define the product and process of manufactured systems;
- Support the exchange and sharing of product information with a minimum of human interpretation;
- Interrelate a broad range of product information to support applications found throughout the product life cycle;

- Define a single, logical representation of product information and application views (content and format).

The product and process information can be grouped into categories. The information is modeled using graphical and computer language techniques. The resultant topical data models contain information related to:

- geometry
- solids
- tolerances
- electrical functions
- material
- presentation
- architectural
- topology
- form features
- layered electrical products
- finite element modeling
- product structure
- drafting
- ship structures

Information modeling is based on a three layered approach. The logical layer is a definition of all the information outlined above. It is a single data model or representation of the data. Also called a conceptual layer, the logical layer is the central model from which the other two layers are derived. The application layer is a subset of the logical layer defining the information for a particular application (design, process planning, inspection, etc.). The physical layer is the definition of the actual file or database containing the PDES data. The PDES physical file format is an example of the physical layer.

The Historical Perspective on PDES

PDES has as its objective to be able to electronically define all the information that's needed to design, manufacture, and support a product. We find some of the early demonstrations of PDES technology relate to being able to define the product's geometry in a computer system, demonstrate the automatic creation of machining instructions and then machine the product that fits that initial product definition geometry. That, as an objective, can be traced back to several things in the past, going as far back as the development of numerical control in the '50s.

If we look at the original objective of the NC development program, we find that the developers were trying to automatically define a part in such a way that

control of the part manufacturing moved off the shop floor and to an engineer in an office. The engineer can control how the machine runs and the products the machine makes. That objective was partially realized in the development of APT. We find in APT the ability to define simple geometry and to define tool paths to manufacture specified geometry.

Defining products in APT was really limited to the simple geometry modeler within an APT program. It was not sufficient to support other downstream applications and other upstream applications to create the geometry in the first place.

Through the 1960s, we have seen the implementation of graphics systems within manufacturing organizations. These systems define and model products, and have become computer-aided drafting systems. There is storage of information about a product and users who want to use it for downstream applications. Throughout the '60s and into the '70s, the development of CAD/CAM evolved in such a manner. We are defining products, we are moving from the ability to put out an automated blue print, to being able to put out geometry information that can drive downstream applications like NC part programming. Once we obtain NC part programming, we want to use it for facets of manufacturing like coordinate measuring machine instruction, and also upstream into the design process to be able to perform design analysis on this CAD/CAM data as well.

In the late 1970s, addressing the need of exchanging CAD/CAM data between CAD/CAM systems, IGES was first created by Boeing, General Electric and the Air Force. The objective of IGES is, again, the ability to exchange a product definition between two different systems. And why do we want to do that? Because we want this information about the total life cycle of the product to become digital and we want to exchange digital information or electronic product description data instead of paper drawings.

From our experience with IGES in the early '80s, the manufacturing engineering community saw there was a need for other information to be stored electronically. Information like the manufacturing intent of a product, or the manufacturing form features as we later called them. In viewing information as it's released from engineering to manufacturing, we see there are several categories of information actually released from design or desired to be released from design, to support applications and manufacturing.

The Air Force funded a program, the Product Definition Data Interface (PDDI), whose objective was to define information needed by manufacturing, created in engineering, to support manufacturing applications.

The PDDI program presented its early results to the IGES organization in 1984. The IGES organization formed the PDES initiation activity. That was actually the first time the IGES organization chartered any activity with relation to PDES and, in fact, was the early genesis of the PDES program.

Design automation, manufacturing automation, the implementation of computers to design and the manufacturing process have all created awareness of the need to share common information about a product and the process used to make it.

We can go back as far back as the '50s to find activities which today can be related to the PDES program, and we can see the objectives, although they have changed with the viewpoints of the technologies available at hand, are very similar. The objective of automating the design and manufacturing process is to achieve the highest efficiency and create the highest quality products at the lowest possible prices.

That, again, is our goal with the PDES program. The PDES activity is addressing:

- the need for exchanging data as we find ourselves in a global manufacturing environment;
- the need for exchanging data with all our different trading partners, both domestic and international;
- the need for exchanging data between manufacturing organizations within a corporation, between a corporation and its suppliers, and between a corporation and its customer.

While related technologies and the technology foundation has changed since the 1950s, we have very much the same objectives as we had then. With new technology we're able to address them again to a more complete stage. We find the PDES program to be addressing the identification, categorization, storage, exchange and sharing of product data throughout the entire product life cycle from its early conceptual design through release to manufacturing, through delivery to the customer, and on through product support.

Architecture For Implementation

PDES will be implemented to satisfy two primary needs: exchanging product data between different applications, and sharing product data between several different applications.

The PDES organization has defined four implementation architectures; two for exchange and two for product data sharing.

Level I Passive File Exchange represents an implementation architecture where product data is transferred from one application to another in a batch process. Level I is similar to the way in which IGES is implemented today.

Application A, which could be a CAD system, creates product data in a file format as prescribed by the PDES organization. That file is then transferred to Application B. Application B has a post processor translator to post process that file into its own native data structure. This transfer can be bi-directional if both applications have a pre- and post-processor. Level I is focused on the exchange of product data between two applications. Level II has the same focus.

Level II Active File Exchange is represented by an application that creates product data in a neutral format. The neutral format has a working form which is a memory resident model of the product data. The two applications, A and B, can reach in to that memory resident model or working form model, and pull out entity by entity the product data it needs. In the exchange process for a Level II implementation, there are two representations of the product data. The exchange file format, or physical format, and another physical form called the working form, which is a memory resident model, that can be accessed entity by entity instead of being accessed in the entire file.

An example of the Level II implementation is the Air Force PDDI program or GMAP (Geometric Modeling Applications Interface) program. Both programs used a neutral form in a physical file format, and a neutral form in a working form memory resident model format. Both Level I and Level II implementation architectures are focused on the exchange of product data between applications. Level III and IV are focused on the sharing of product data.

Level III Shared DataBase Implementation has a logical description of all the product data and a physical implementation of this information in a database format. Applications can then reach into that database and pull out the information they need to drive their specific application. An example would be a relational database with several applications driving from that relational database. Using the data dictionary, which describes data in the database, the applications then have the capability to ask the database manager for pieces of product data it needs to do its job and can provide back end resultant data to be stored into the product definition database. The Air Force Integrated Design System or IDS system, developed by Rockwell, provides a good example.

A Level IV Knowledge Base Implementation of PDES is represented by using an object oriented approach to the storage of product definition data where the product data and methods to operate on that product data are stored together as an object in an object-oriented database. This knowledge base representation is the desired implementation environment and is a limited prototype implementation of a Level IV as it is performed today. Currently, Level IV is not widely implemented throughout industry and the vendor community.

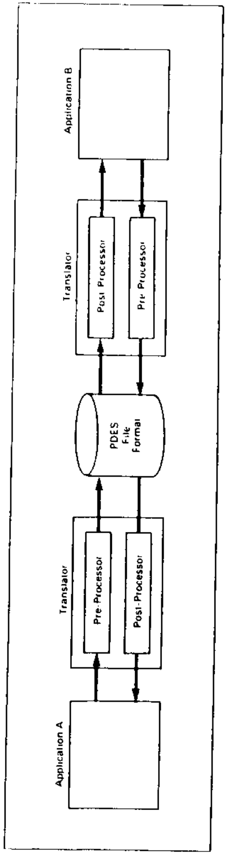

Figure 2. Level I Implementation—Passive File Exchange.

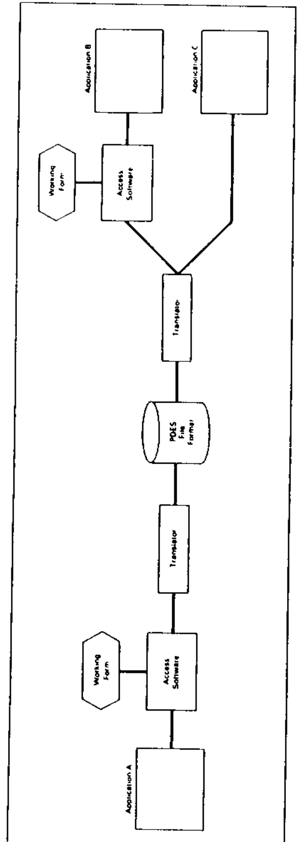

Figure 3. Level II Implementation—Active File Exchange.

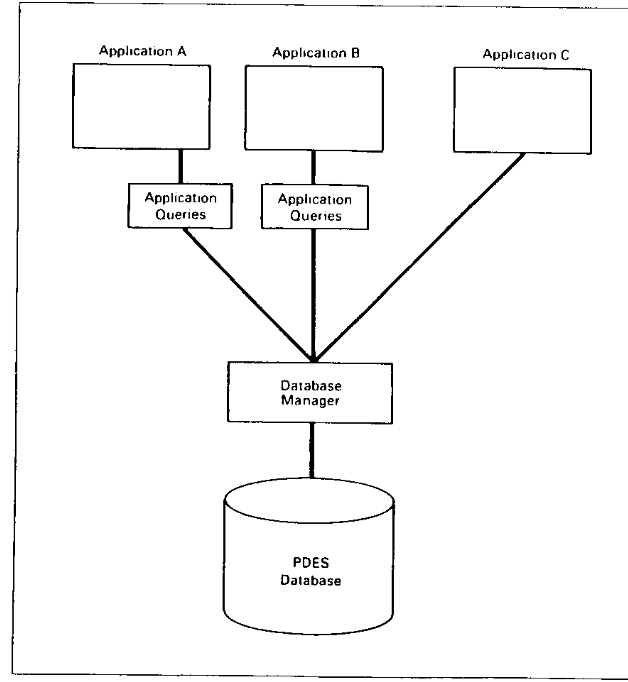

Figure 4. Level III Implementation—Shared Database.

PDES Inc. Program

The PDES Inc. program is an industry-funded cooperative project to accelerate the development and implementation of PDES within industry. The program is using a combination of industry provided personnel knowledgeable in PDES technologies and hired contractors working together focusing on the development of the PDES specification.

The background of the PDES Inc. program dates back to the fall of 1986. Individuals from a few aerospace companies worked with the United States Air

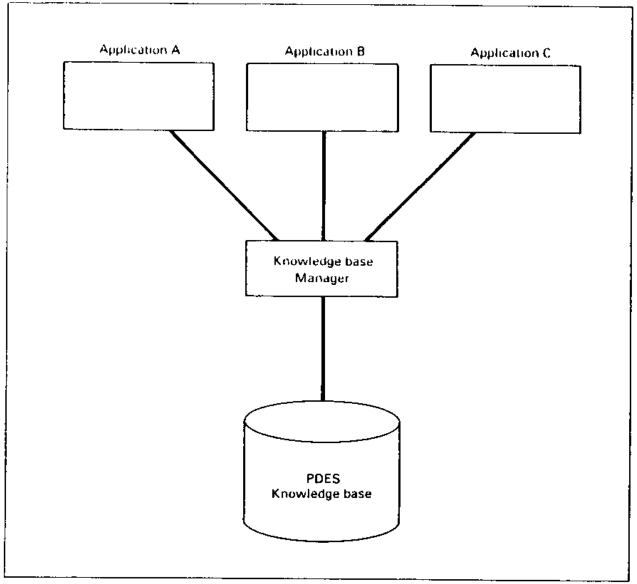

Figure 5. Level IV Implementation—Knowledgebase.

Force Manufacturing Technology Division at Wright Patterson Air Force Base to develop plans for a program to accelerate the development of PDES. Looking at several alternative methods for funding the overall development program, these companies decided to focus on an industry-only membership, where government participation would be in a non-funded involvement.

This activity grew until the development of a interim PDES Inc. planning activity, formulating the initial technical development plan for the PDES Inc. Program, and managing the release of a request for proposal for a PDES Inc. host contractor.

The South Carolina Research Authority (SCRA) teamed with Battelle Laboratories, Dan Appleton Company, International Technegroup Incorporated and Arthur D. Little, to create a proposal to be the host contractor and to provide technical resources for the management of the technical work to be done on the

PDES Inc. program. The PDES Inc. board of directors awarded the contract to SCRA and its technical team in August, 1988. The contract officially was kicked off in September of that year with a technical team meeting of the initial professionals from each of the member companies and technical subcontractors involved in the project.

The PDES Inc. program is divided into two major phases; each phase lasting 18 months. In Phase One, the objective is to develop a Level I or Level II implementation of PDES. In Phase Two, the objective is to develop a Level III implementation of PDES.

The team of people is organized into three working groups as shown in Figure 6: the Model Integration Team, the Model Test and Validation Team and the Technical Products/Implementation Team. In each of these three groups, a team leader was chosen from one of the member companies. A technical subcontractor and personnel from the different member companies were also assigned to each group.

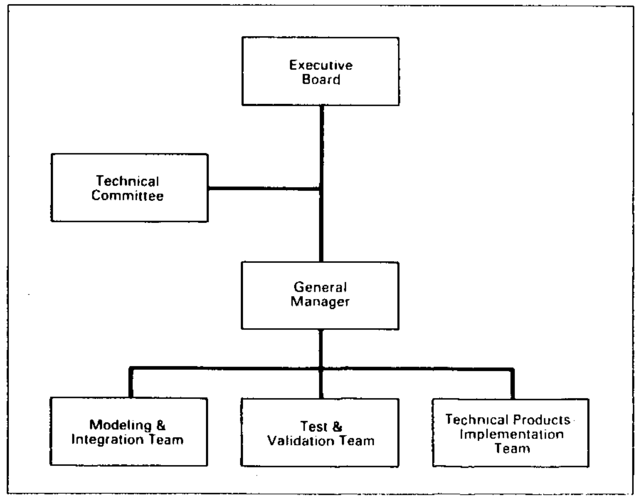

Figure 6. PDES, Inc. Organizational Structure.

An important philosophy expressed by the PDES Inc. program defines the relationship of its proprietary results with the PDES volunteer organization. In the spirit of cooperation, PDES Inc. will provide suggested changes to information models received from the volunteer group. The changes will be generated by the PDES Inc. process of modeling, integration, test, validation and implementation of PDES data models. The process and relationship are depicted in Figure 7.

In addition to the three working groups, there was a Configuration Control Board and a Systems Integration Board comprised of the host contractor general manager, the team leaders from the working groups, and the technical subcontractors. An important link was established between the PDES Inc. program and NIST National PDES Testbed. NIST became the PDES test laboratory and provided personnel to the PDES Inc. program to help with testing and implementation. NIST received a contract from the Department of Defense to provide these types of services by establishing the PDES National Test Laboratory.

A company can choose to become a member at one of three levels: A Class I member, which is the highest class, pays $100,000 per year, plus provides two technical people for the working groups. In addition, there is a $50,000 travel and equipment budget provided to each of the technical people. Class I members have membership on the board of directors as a voting member and will own all rights to all deliverables in the PDES Inc. program.

A Class II member pays $50,000 a year and provides one technical person to the working groups, has a seat on the board of directors in a non-voting capacity, and has the same rights of ownership to the results of the PDES Inc. program.

The third class is an observer class. The fee is $25,000 a year and there is no requirement to contribute technical labor. There is also no resulting ownership in the results of the PDES Inc. program.

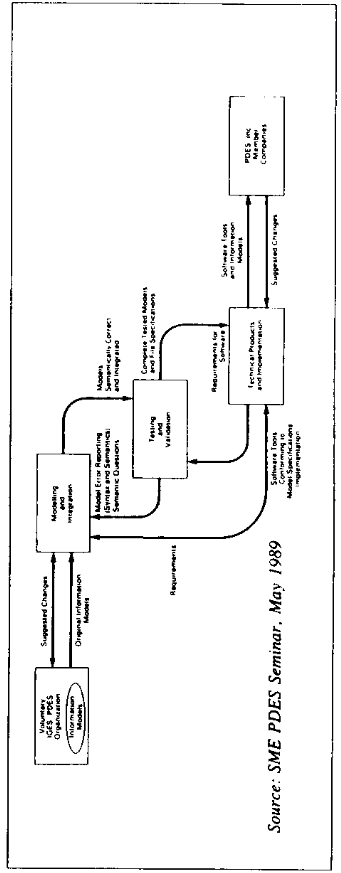

Figure 7. PDES, Inc. Relationship with PDES Voluntary Organization.

Table One shows the membership as of September, 1989.

Class I	*Class II*	*Class III*
Boeing	LTV Aerospace	Honeywell
General Dynamics	Rockwell	
General Electric	Prime Computers	
Grumman	DEC	
Lockheed	FMC	
McDonnell Douglas	Westinghouse	
Northrop	Newport News Shipbuilding	
IBM		
Martin Marietta		
General Motors		
United Technologies		

Table 1. PDES Inc. Program Membership

The PDES program will deliver results to member companies that they can incorporate into their CALS activity. CALS, a Department of Defense (DoD) initiative, is designed to use PDES technology in its Phase II programs. It has been supportive of the start up of PDES Inc., has encouraged companies to join the program and, continues to be a strong advocate of this program.

The planning people in charge of the CALS activity at the DoD see the PDES Inc. program as providing PDES results to be used as the cornerstone of the data content and data delivery in a CALS Phase II environment for the future.

The Benefits Of PDES

If we look at the process of manufacturing from a bottom-up functional view, we find the introduction of computer technology can lead to the automation of several of those discrete functions. Each implementation of automation itself becomes a small island of automation. That automated function typically has involved with it a user interface, some kind of functionality or algorithm coded into a software program, some kind of data input, data output and data storage. The data repository that becomes the culmination of running this automated function several times becomes a small database.

As we look across the spectrum of manufacturing functionality from design through manufacturing to product support, we see that a great deal of information

about our business is stored in discrete implementations of technology. Implementations that are not interchangeable. Implementations that cannot be integrated to reside on top of other databases or use information generated by other automated functions.

This is the problem we face today as we attempt to implement new technologies that may change a particular functional application. Every time we do this, we face the investment of changing our technology. That is expensive and time consuming.

As an industry, we need to begin to store information in a form we can retreive year after year and still use even if it is in a different form of automated functions. With the rate of technological change we have today, we are unable to accomplish this without a PDES capability. We cannot, for example, come back in five years with the same CAD/CAM system and expect to retrieve the same engineering model that we had. The technology changes too fast. And, with new technology we are eliminating paper. We have paper engineering drawings that are 100 years old. Paper has been an outstanding form of interface between various functional applications. Primarily, because a human was involved with each one of those functional applications.

Now, we have automated applications, computer aided design/computer aided manufacturing, engineering analysis, all are done on computer. Inspection, too, is done with computer-driven machine tools. Automated assembly and automated material handling have as a function some computer automation, which requires information input and generally creates information output.

The total sum of this information is what we've defined earlier as product data; data that defines the product and the process used to manufacture it.

We've made attempts before to define neutral formats for storage and retrieval. One significant attempt is IGES. And, although IGES is used very heavily in the exchange of engineering information between two different CAD systems, it has not been successful in the long-term storage and retrieval. IGES simply was not designed to do that. It contains a file structure and a format which does not provide easy storage. The PDES organization needs to be considering that. PDES needs to be addressing the implementation levels that we've talked about between exchange and sharing of information. It also needs to be addressing the long-term storage and retrieval of product data.

The importance of PDES from a business viewpoint is that it will provide not only the format for storing and archiving information and the format for exchanging it, but the definition of that information so we can create automated applications which link directly to the PDES structure and automated applications which can use PDES information to perform their functional capability.

It is important for those of us involved in the development and use of PDES to recognize the limitation and scope of PDES. PDES as a technology will provide the capability to exchange and share information. PDES as a technology does not answer all the questions faced by information management. While PDES addresses the information flow into and out of all the functional applications within a company, it does not address the organization of the company's handling of information, nor does it address the management of information within the company.

You, as a manufacturing professional, still need to address the capability of handling information within your company. The format and content of that information can now be changed because of the introduction of PDES. With PDES, we can handle the information in an electronic form and can define enough structure into that information to fill that form with as much intelligent information about the product and the process as possible, and still drive all the different functional applications in the manufacturing enterprise.

The information management within your own business may yet become another functional application within your manufacturing enterprise. As you approach what has been called a *computer integrated enterprise*, capabilities provided by a PDES specification and PDES implementation software will assist you in the implementation of new technology so you can achieve an overall integrated enterprise.